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CHAPTER 6.000

SOILS, GEOTECHNICAL, AND HYDROGEOLOGICAL REVIEWS

Soils and/or geotechnical reviews are required for all applicable development activities as specified in this manual and hydrogeological reviews are required for specified development activities that will rely upon or may potentially impact groundwater resources. The extent of these reviews is directly related to engineering and/or environmental impacts of the proposed development. In an effort to standardize these reviews and to document that all factors have been considered, Loudoun County has formulated a systematic approach to soils, geotechnical, and hydrogeological requirements. Chapter 6.000 and the criteria for these reviews are divided into Soils and Geotechnical / Geophysical Reviews, which are defined in section 6.100, and Hydrogeological Testing, which are defined in section 6.200.

6.100 SOILS AND GEOTECHNICAL REVIEWS

Soils and geotechnical reviews as defined in this document are evaluations of local soil conditions, the potential effects those soil characteristics may have on the proposed development or land use, and the potential effect the proposed development activity and land use changes may have on the soils and associated landforms.

6.110 TYPES OF SOILS AND GEOTECHNICAL REVIEWS

The County recognizes that there are many types of soils and geotechnical investigations and reports. Many reports will not conform to these standards and will not have to be submitted to the County. However, where County ordinances or this manual establish a requirement for such reports to be submitted to the County, it is in the applicant's, as well as the County's, best interest to insure all reports are complete and speak to the needs of the project. This report should insure that costly delays and misunderstandings will be avoided and that the quality desired by all will result.

6.120 SOILS MAP CERTIFICATION

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The purpose of the soils map certification is to serve as a screening mechanism to identify those tracts of land or building sites, or parts thereof, where Class III and/or Class IV soil classifications exist. To provide a soils map certification, the following criteria shall be followed:

- A. The applicant shall review the latest adopted County soils map for the subject tract to determine the existing soil conditions.
- B. Land development applications for preliminary plans of subdivision, site plans, and construction plan and profiles shall contain:

- 1. A maximum 1:2400 scale (1 inch = 200 feet) copy of the proposed development layout, overlaid on the County soils map, including the soils, drains, spot points, and a soils table with mapping unit name and number, hydrologic class, general development class, and identifying hydric soils. Once a Preliminary Soils Review (PSR) has been completed for the property, the above information shall be updated, and;
 - 2. A note stating whether or not Class III and/or Class IV soils exist on the development site per the following:

"The subject development site does (or does not) contain Class III and/or Class IV soils, per the latest County soils map as identified by the Interpretive Guide to Soils Maps, Loudoun County, Virginia, or per the approved Preliminary Soils Review Investigation and Report."

Such statement, once approved by the Director or his designee, constitutes the soils map certification.

6.130 PRELIMINARY SOILS REVIEW INVESTIGATION AND REPORT

The Preliminary Soils Review is to be prepared by or under the direction of a Virginia Certified Professional Soil Scientist (C.P.S.S.), Licensed Professional Engineer (P.E.) or Certified Professional Geologist (C.P.G.).

The County can generally provide a Preliminary Soils Review to the applicant within 30 days of such request, provided:

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1. The applicant bears the cost of soils and topographic maps required to complete the review;
2. Field stake-out is provided, when requested by the County, to adequately identify specific soil characteristics within proposed disturbed land area.
3. The applicant provides a backhoe and operator to the County for soil observation, if required based on seasonal or climatic conditions or stoniness.

If desired, the applicant may have such a report prepared by qualified consultants, in accordance with the guidelines of this chapter. Reports prepared by a consultant shall be submitted for review and approval of County staff.

- A. The scope of a Preliminary Soils Review is to provide detailed soil mapping for the subject study / review area. It is intended to verify and augment the detail of the most recent Loudoun County Soil Survey and determine the general constraints related to the suitability of an area for some use or combination of uses. The Preliminary Soils Review must address the areas proposed for development and/or land disturbance. A separate Preliminary Soils Review shall be required prior to development and/or land disturbance of any areas of a given parcel or lot of record that were not included within a prior Preliminary Soils Review. Descriptions of soils and landscapes are appropriate for this review, which will rely heavily on a soils map and literature review, with site specific fieldwork to confirm published mapping or actual mapping of a tract of land. Field verification of the County soils map, or identification of required changes, must be conducted in accordance with the National Cooperative Soil Survey standards as set forth in the "National Soil Survey Handbook". The review report shall identify the mapping units as set forth in the Interpretative Guide to Soils Maps, discuss characteristics of the mapping unit, potential problems with proposed uses, and potential remedial actions, if available. The source of descriptions and their use potential ratings shall be documented, whether from a published report or actual field borings.
- B. The Preliminary Soils Review report shall include the following:
 1. Background
 - a. A description of the site location and terrain.
 - b. A brief description of bedrock geology and associated surface

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materials.

- c. A description of field methods and procedures.
- d. A description of laboratory methods and procedures, if used.
- 2. Scope of Project and Objectives
- 3. Narrative of Standard Terminology, if required
- 4. Report of Field Investigation (verification of, or recommended changes to, the County soil map and variations to the soil mapping units identified on the official Loudoun County legend).

C. The report of investigations shall contain the following:

- 1. A soils map, drawn to 1:2400 scale (1 inch = 200 feet) or larger, as desired, on sheet(s) 24 inches by 36 inches. Where small tracts are the subject of review (typically less than 12 acres), an 8 1/2-inch by 11-inch sheet may be used, provided it is at the 1:2400 scale and complies with all the requirements herein. Soil map(s) shall show the following:
 - a. The following information as per the Loudoun County planimetric base maps:
 - 1. Topography, with at least 5-foot contour intervals.
 - 2. Planimetric detail, including swamps, marshes, ponds, wooded areas, buildings, roads, fence lines, utility structures, etc.
 - 3. Approximate Coordinate Grid System, at 1,000-foot intervals, with complete annotation.
 - 4. Location map, at 1 inch = 2,000 feet, north arrow and approximate grid coordinate information.

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- b. The general location and extent of soil mapping units for the tract and other soil/landscape features, including stone symbols, gullies, rock outcrop, springs, and sinkholes or other karst features.
 - c. General location of all borings and backhoe pits. Test holes/pits are to be numbered.
 - d. The proposed development plan as related to the mapped soil units.
2. Minimum Soil Boring Densities
- The number of observations must be adequate to evaluate each landscape position, geologic formation and map unit according to the National Soil Survey Handbook. Tracts of 100 acres or less require 1 boring/5 acres. Tracts greater than 100 acres require 1 boring/5 acres for first 100 acres, and 1 additional boring per 10 acres or fraction thereafter. The minimum number of borings required is 4. Boring density must be sufficient to evaluate each landscape position and geologic break within the area to be mapped.
- 3. Descriptions of mapping units, including range in characteristics, slope, texture, color, structure, permeability, drainage, landscape position, parent material, presence of perched or ground water table, depth to rock and other site characteristics such as karst features, identified as Karst Sensitive Environmental Features within Zoning Ordinance Section 4-1900.
 - 4. Narratives on mapping unit potential for proposed uses. Notes: Boring logs, field notes, field/laboratory data should be available for review if requested. (Refer to the Interpretative Guide to the Use of Soils Maps, Loudoun County, VA.)
 - 5. The following should be placed on the map and report, signed by the registered professional, and stating that: "The field work verifying this soils map has been completed by a Virginia Certified Professional Soil Scientist, Engineer or Geologist as required in Chapter 6 of the Facilities Standards Manual for Loudoun County."

"This report has been written by a Virginia Certified Professional Soil Scientist Engineer or Geologist as required in Chapter 6 of the Facilities Standards Manual

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for Loudoun County. This report was developed for submission to the Department of Building and Development which shall be notified, in writing, of any changes (amendments) to this report."

Signed _____ Date _____
Certified Professional Soil Scientist/Geologist/Engineer Certification

D. Recommendations/Conclusions (As appropriate for proposed use)

1. Preliminary summary of soil/rock problems and their extent for proposed uses.
2. General recommendations on needs for drainage (foundation under drainage and/or curtain drains for sewage disposal systems).
3. General recommendations for undercutting high shrink-swell materials.
4. General recommendations on frost heave potential.
5. General recommendations on use suitability of soil materials for road fill and fill under slabs.
6. General recommendations for application of topsoil and vegetative stabilization (lawns and shrubs).
7. General recommendations on soil corrosivity.
8. Recommendations for a geotechnical and/or geophysical study (Section 6.150 of this chapter), if needed.
9. General recommendations for on site sewage disposal.

6.140 DETAILED SOILS/SITE INVESTIGATIONS

Detailed soils/site investigation reports for all proposed on site sewage disposal systems and facilities including those which are not exclusively regulated by the State are to be submitted to the Loudoun County Department of Health in accordance with County Code and current State

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regulations, where applicable. Prior to conducting the detailed soils/site study, which requires any land disturbance or tree removal in the Mountainside Development Overlay District, Limestone Overlay District and within areas of steep slopes, a conceptual site layout must be provided and approved by the Department of Building and Development. Necessary excavation of potential drainfield sites shall be performed by hand and not by using equipment that may require clearing and grading for access to the sites.

In addition, a detailed soils/site investigation may be required to determine the suitability or limitations of a particular tract of land for any land filling operation, solid waste operation, composting facility or other similar use. The investigation may require physical or chemical analyses, either in situ or on selected samples in a laboratory. The intensity of investigation should be sufficient to provide information for immediate use or planning decisions. The technical standards for a detailed soils/site investigation for a land filling operation, solid waste operation, composting or other similar use are set forth in the Codified Ordinances of Loudoun County and current State regulations, where applicable.

6.150 GEOTECHNICAL STUDIES

Geotechnical Studies are to be prepared under the direction of, and sealed by, a registered Professional Engineer licensed in the State of Virginia with experience in geotechnical engineering specific to the underlying geology. Geotechnical Studies shall not be required in areas where development and/or land disturbing activities are not proposed.

Requirements for Geotechnical Studies

- A. A Geotechnical Study shall be required for all public and other infrastructure improvements located where known soil conditions may generate problems relative to the planned land use as identified by the Preliminary Soils Review, including private streets and other infrastructure facilities (such as storm drainage and stormwater management), which require performance bonding with the County.
- B. A Geotechnical Study shall be required for all soil classifications for proposed impoundment dams for retention in accordance with Chapter 5 of this manual or where any road or driveway serving two or more residences crosses a proposed or

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existing dam. Development of all other public and private facilities shall not require a Geotechnical Study unless the specific need is identified and requested by the County at the time of preliminary subdivision and/or site plan, whichever is applicable.

- C. Laboratory data and field measurements, such as subsurface stratification and ground water levels, shall be provided to document findings and design parameters. Maps shall be provided to illustrate major conclusions. The report shall address areas impacted by the proposed construction. It shall contain preliminary appropriate designs and earthwork specifications, and recommendations for remedial action in problem areas.
- D. Boring densities must be in accordance with section 6.153 of this manual, and as required by the Building Official..
- E. If the Geotechnical Study is within the Limestone Overlay District, the report must identify and address the required Geophysical Study in accordance with 6.151 of this manual.

6.151 GEOPHYSICAL STUDIES

Geophysical Studies are to be prepared under the direction of, and sealed by, a registered Professional Engineer licensed in the State of Virginia or by a Virginia Certified Professional Geologist in consultation with an engineer. The person preparing the study must have experience in geophysical analysis, geotechnical engineering and should have an understanding of the underlying karst geology. Geophysical Studies shall not be required in areas where development and/or land disturbing activities are not proposed. Geophysical Studies may be performed to augment and/or verify a geotechnical report. Within the Limestone Overlay District (“LOD”), geophysical studies will be required to identify and address karst features in areas of proposed land disturbance. Geophysical Studies may also be required for proposed landfills, quarries or other special uses or as directed in a Preliminary Soils Review.

- A. Requirements for a Geophysical Study:

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1. Geophysical Study (determined by ground penetrating radar, electromagnetic properties, electric resistivity, microgravity, seismic or other investigative techniques) must identify and address any anomalies or areas of voids, rocks, saturated soil, mud-filled voids, and all Karst Sensitive Environmental Features revealed by the Preliminary Soils Review, or the Geophysical Study. ~~or contained in the LOD Database.~~
2. Field measurements, such as subsurface stratification and ground water levels, shall be provided to document findings and design parameters. Maps shall be provided to illustrate investigations of karst features and major conclusions. The report shall address areas impacted by the proposed construction. It shall contain either appropriate recommendations for remedial action in problem areas or recommendations for borings to verify significant geophysical anomalies and findings within ~~35~~ 45 feet of the surface or as directed by the Director.
3. For LOD areas geotechnical studies and borings must be performed after the geophysical study to verify and address any potential karst features indicated by the geophysical study.
4. Boring densities must be in accordance with section 6.153 of this manual.
5. When borings are required provide geotechnical testing and evaluation by continuous Standard Penetrometer Test soil borings to a depth of 45 feet. Should the borings with a Split Spoon Sampler encounter refusal prior to a depth of 35 feet, the boring shall be moved adjacent to the initial location until the depth is achieved, or extended by other means into the obstruction an additional depth of 5 feet. All borings attempted in the LOD shall be abandoned with either bentonite or neat cement, recorded and certified by the driller and certified by the supervising Licensed Professional Engineer/Certified Professional Geologist on the boring log for each attempted boring.

B. Alternative Methodologies for Geophysical Studies

To best address site specific characteristics, an alternative methodology (i.e. a list of alternative requirements) to those listed in subparagraph A, above, may be submitted to the Director for review, and revision if needed. If approved by the Director, such alternative methodology shall be followed in lieu of subparagraph A., above.

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6.152 ADDITIONAL REPORTING REQUIREMENTS FOR GEOTECHNICAL AND GEOPHYSICAL STUDIES

The geotechnical or geophysical report shall specifically address structural improvements proposed on soils with problematic conditions or properties such as high shrink-swell clays, high water tables, known low-bearing capabilities, and areas which have potential geomorphic instability per the Interpretive Guide to Soils Maps, Loudoun County, Virginia. The Geotechnical or Geophysical study shall be in compliance with the guidelines specified herein and as applicable in section 4-1900 of the Revised 1993 Zoning Ordinance as amended. The study shall reflect the particular structures and facilities in the development proposal.

The report shall address areas of the site impacted by proposed construction. It shall contain approximate designs, earthwork specifications, and recommendations for remedial action in problem areas. The Geotechnical and/or Geophysical report shall contain the following:

- A. Background
 - 1. A brief description of the terrain.
 - 2. A brief geological history.
 - 3. A description of exploration, equipment and sampling methods.
 - 4. A description of laboratory test procedures and results.
- B. Scope of Project and Objectives
- C. Narrative of Standard Terminology, if Required
- D. Report of Field Investigation

The report of field investigation shall contain the following:

- 1. Maps and Drawings

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A map, drawn to 1:2400 scale (1 inch = 200 feet and larger, as desired), and other maps as needed, on sheet(s) 24 inches by 36 inches. Where the proposal covers more than one sheet, a compiled photo-reduction, at 1:12,000 scale (1 inch = 1,000 feet) of all maps shall be submitted in addition to the 1:2400 scale maps. Where the proposed site consists of less than 5 acres, maps at 1 inch = 50 feet scale or larger may be submitted. Maps shall show the following:

- a. The following details, per the Loudoun County planimetric base map:
 - i. Existing topography, with at least 5-foot contour intervals.
 - ii. Within the LOD, proposed topography, with at least 2-foot contour intervals.
 - iii. Existing planimetric detail from base map and field observations, including swamps, marshes, ponds, wooded areas, rock outcrops, karst features, buildings, roads, fence lines, utility structures, etc., and, within the LOD, include sinkholes, based on what is shown on the ~~County's Karst Feature Database, on the~~ Preliminary Soils Review, and on additional sites observed during the Geotechnical and/or Geophysical investigations, and planimetric detail.
 - v. Property and Site boundary lines.
 - vi. Approximate grid coordinate system in 1,000 foot intervals with complete annotation.
 - vii. Location map, at 1 inch = 2000 feet, with north arrow and approximate Coordinate Grid information.
- b. Location of all test holes, borings, backhoe pits, geophysical data collection lines (such as, resistivity lines, *etc.*) and/or seismic tests on a soils map approved by the Director. Test holes/pits shown on the soils map are to be numbered and located dimensionally. Boring log records shall include surface elevations based upon County topographic maps. Boring densities shall follow the criteria of Section 6.153.

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- c. The general spatial distribution of the various soils and geologic materials. Particular attention shall be paid to identifying and delineating areas where soil factors are expected to mandate modifications or special designs for proposed construction.
- 2. Cross-sections based upon County topographic maps of soil/geologic materials, showing stratigraphic relationships, including structure, and subsurface distribution.
- 3. Narratives describing geology and hydrology.

- a. General

For development proposals not described in subparagraph (2b) below, a general geologic report will be sufficient and must include the following:

- i. Narrative of location, type, and hardness of bedrock encountered; evaluation of expected rippability.
 - ii. Ground water conditions, including depth and type of aquifer, based on current published information.

- b. Detailed Geology/Hydrology

A detailed section on geology and hydrology, evidenced by appropriate drill hole data and/or test pit data, shall be required when one or more of the following uses are proposed:

- i. Extraction of Natural Resources.
 - ii. Dams/impoundments over 15 feet in height or 25 acre feet in impoundment capacity, as required per Chapter 5.
 - iii. Land development proposed in mountain colluvium (mapping unit numbers 27C, 52E, 59C, 88C, 88D, , 89D, and 89E) with slopes greater than 12 percent.

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iv. Landfills.

The section shall include, as appropriate:

- (a). Type(s) of rock materials present, including structural, stratigraphic, physical, chemical, and mineralogical properties, description of mapping units (geologic formations if more than one are shown on the map).
- (b). Macro- and micro-structure of rock or geologic material, including joints and fracture patterns; faults, if present; cleavage; foliation and bedding, if applicable.
- (c). Geologic map and cross-sections of the tract. At least two of these cross sections shall show elevation of the water table (i.e. hydrogeologic cross-section).
- (d). Directions of groundwater movement in both soil and geologic materials; method of recharge; dewatering effect of proposal; map showing groundwater contours; transmissibility of rock; effect of regional fractures (linear fractures) on water movement; discussion of existing ground water supply; discussion of existing levels of water; historic water availability.
- (e). Environmental geology. Susceptibility of area to pollution from site-industry products, leachate, or surface contamination (such as landfills and sewage disposal facilities), and extraction of natural resources. This section of the report shall specifically address the potential of area to undergo catastrophic collapse, presence of slip plains, sinkholes, and shock transfer or the presence of asbestos content in rocks.
- (f). Geophysical data (i.e. the result of ground penetrating radar, electromagnetic properties, electric resistivity, microgravity, seismic or other instruments) is required. All

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applications shall comply with State solid waste laws/or other environmental regulations.

- (g). Economic geology. (Required only for the extraction of natural resources.) Information needed for estimated length of extraction time for removal of natural resources and evidence of proven reserves.

4. Narratives describing soils and surface materials.

For all other areas impacted by construction proposals, a detailed description of soils and surface materials illustrated on the map (Section 6.150.E.1) will be required and should include the following:

- a. Description of physical properties for soils in each affected mapping unit or area of similar soil conditions or "strata," including silt content, clay amount, and type (shrink-swell, plasticity, bearing capacity of materials, chemical properties), particularly as these apply to revegetation, apparent stability of sidewalls in cuts.
- b. Description of surface drainage, permeability, and presence of seasonal perched water tables.

- E. Recommendations/conclusions section, which shall address all of the above information and contain recommendations/conclusions as required by Section 6.154.

6.153 BORING DENSITIES

Boring density may include borings, test holes, backhoe pits, and geophysical investigative techniques, and seismic tests. The number of observations must be adequate to evaluate each landscape position and/or geologic formation. Geophysical investigative techniques may be used to reduce the minimum boring densities in the LOD.

- A. Roads and Streets: Boring densities for proposed road and street construction shall, at a minimum, reflect the specifications contained within subparagraphs 1, 2, and 3 below unless adequate justification for varying such densities is provided as part of the geotechnical report, and is signed and sealed by the registered professional:

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1. As recommended by the Director at the time of preliminary subdivision or site plan, whichever is applicable, in Class I and Class II soils, as identified by the Interpretive Guide to Soils Maps, Loudoun County, Virginia.
 2. One boring per 250 feet, or fraction thereof, in Class III and Class IV soils, as identified by the Interpretive Guide to Soils Maps, Loudoun County, Virginia.
 3. Borings in areas of transition from Class I and II soils to Class III or IV soils shall be spaced sufficiently to accurately estimate the location of soil change.
- B. Boring densities for impoundment dams and other public improvements, which require performance bonding, shall be as follows:
1. Borings shall be located to be representative of the variety of land forms and geologic formations contained within the specific development site.
- C. Structures and Retaining Walls.
1. Boring densities associated with the building permit process will be determined on an individual basis by the County Building Official, as defined in the Virginia Uniform Statewide Building Code.

6.154 RECOMMENDATIONS/CONCLUSIONS

The following are areas which shall be included in the recommendations and conclusions section, as appropriate:

- A. Structures, Roads, Dams and Retaining Walls
1. Recommendations for feasible foundation types,
 2. Recommendations for typical California Bearing Ratio (CBR) values and identification of potential subgrade stabilization problems or special pavement design requirements.
 3. Recommendations on feasibility of slab on grade versus supported ground floor construction.

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4. Allowable soil bearing values at all bearing locations and elevations.
5. If soil conditions indicate, recommended pile type, loading, tip elevation, etc.
6. Recommended bearing values of rock based on unconfined compression tests, pressure meter tests, triaxial tests.
7. Conclusion that rock strata are sound and not underlain with solution channels that would affect the allowable bearing loads or provide recommendations for correction of these conditions.
8. Ground water elevations and recommendations for temporary dewatering procedures during construction and for permanent dewatering facilities after construction, including effects of seasonal variations.
9. Other factors, such as alkali content, corrosivity, underground springs, fill areas, maximum depth of frost penetration, etc.
10. Thickness, consistency, character, compressibility, shear value, safe bearing value, etc., of the various strata encountered.
11. Recommendations for removal of perched/seasonal water tables, including foundation drainage, under drainage for roads, and feasibility of subgrade walls with finished living space.
12. Specifications for fill materials, including gradation ASTM, AASHTO, or VTM test method and percent of maximum theoretical density and optimum moisture, site preparation and material placement, qualifications of testing personnel and testing laboratory.
13. Recommendations to accommodate shrink-swell clay.
14. Recommendations to control differential settling.
15. Shoring for utility or other deep excavations.
16. Recommendations for design lateral pressure for below grade foundation walls.

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B. Landfills

1. Refer to Chapter 1080 of the Codified Ordinances of Loudoun County.

C. Extraction of Natural Resources

1. Analysis of controlled blasting vibrations and their potential effects on structures near the proposed facility.
2. Recommendations for monitoring programs for blasting vibrations and ground water supplies, including location and number of observation points and frequency of sampling.

D. Additional Recommendations/Conclusions within LOD

1. Within the LOD, the report must include conclusions as to the risks of ground surface collapse and groundwater contamination for the proposed location and use.
2. Within the LOD, the report must include recommendations of measures to mitigate the potential for ground surface collapse pursuant to Zoning Ordinance Section 4-1908.
3. Within the LOD, the report must include recommendations of measures to mitigate potential adverse impacts of pollution on surface water, or groundwater, or springs pursuant to Zoning Ordinance Section 4-1908.
4. When blasting is required, the report must include a recommendation as to the need for post-blasting field inspection and/or additional geophysical investigation.

6.155 SOILS BORING LOGS

The following shall be provided with these studies and reports, if applicable:

- ### A. Boring/test pit number.

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- B. Approximate surface elevation.
- C. Approximate elevation, thickness, description (ASTM 2487, ASTM 2488), and classification of each soil stratum.
- D. Location of all samples taken and field tests or laboratory analyses conducted.
- E. Location and identification of rock; indicate soundness.
- F. Location of water table and 24-hour water levels.
- G. "N Values" (standard penetration test results) and natural moisture content ("W") from split-spoon and/or Shelby tube samples.
- H. Other samples/tests to be performed.
- I. Name of company performing the field operation and the name of the contact person at that company who is familiar with the field operation.
- J. Ground water monitoring data.
- K. Seismic or other geophysical data for site.
- L. Rock core descriptions.

6.156 LABORATORY DATA

All laboratory data should be supplied as required to support recommendations and description narratives.

6.157 BLASTING IN LIMESTONE OVERLAY DISTRICT

All blasting conducted in the Limestone Overlay District the County shall require the following:

- A. A blasting plan shall be submitted to the Director for approval that contains blasting procedures, blast layout, explosives descriptions and quantities, drill logs, water sampling data, structural pre-blast surveys, etc. The plan should identify any water wells, springs, or

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streams within a 1000' radius of the blast location; and any structure within 500' radius of the blast location.

- B. A pre-blasting site inspection and Geophysical study to determine base-line conditions, and the potential for solution channels or cavities below the blasting site.
- C. The applicant shall contact and notify, in writing, the owners of wells within a 1000' radius of the proposed blasting location and offer to sample and test the water in a pre-blast condition.
- D. The applicant shall contact and notify, in writing, the owners of structures within a 500' radius of the proposed blasting location, and complete a pre-blast survey to document the condition of the structure.
- E. Monitoring of all blasts by appropriate seismic and noise measurements at sensitive locations identified in the blasting plan;
- F. Post-blasting inspections and/or post-blasting Geophysical Study when required by Geophysical Report.
- G. Mitigation, as needed, based on the post-blasting Geophysical Study, and well water and structural damage complaints.
- H. Restrictions on blasting and explosives, or limits on blasting to specific times and atmospheric conditions to minimize impact.

6.158 NUTRIENT MANAGEMENT PLANS IN LIMESTONE OVERLAY DISTRICT

A nutrient management plan in accordance with DCR Standards and Criteria and §10.1-104.2 of the Code of Virginia and 4 VAC 5-15 as required per the Loudoun County Zoning Ordinance, Limestone Overlay District.

6.159 STRUCTURE/BUILDING PAD CONSTRUCTION WITHIN THE LOD

Any structure built in the LOD shall be verified and certified in writing to the Director that the building pad proposed in the site development plans and built in the site construction process, is sufficient in size, compaction, and subgrade materials to support the proposed structure applied

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for in the building permit application. In furtherance of this requirement the following shall also be required:

- A. The entity performing construction monitoring and testing shall acknowledge, and submit in writing, prior to commencing work, that they have obtained and reviewed the requirements of the detailed geotechnical report.
- B. The entity performing foundation monitoring and testing shall acknowledge, and submit in writing, prior to commencing work, that they have obtained from the county or from the entity responsible for the construction monitoring and testing, all construction and monitoring/compaction testing reports and have reviewed the reports. Such acknowledgement shall also include a disclosure of any possible deficiencies, anticipated impacts to foundation construction for any proposed structure, and proposed corrective measures to rectify any deficiencies.
- C. The entity responsible for approving foundation subgrade shall verify, in writing, that all prior work done for the building pad construction meets a reasonable standard of care prior to performing any subsequent work.

6.160 IMPLEMENTATION OF RECOMMENDATIONS

The design engineer/architect will provide the Chief Building Inspector and the Director of Building & Development with a written statement stating that he has reviewed the plans and, as submitted, the plans were prepared in accordance with the recommendations of the Geotechnical / Geophysical report.

6.161 STANDARD REFERENCES, METHODS, AND PROCEDURES FOR SOILS AND GEOTECHNICAL STUDIES

The following will be considered standard reference manuals and publications:

- * Black, C.A. (ed.), 1965. Methods of Soil Analysis: Parts I and II, Agronomy Series, American Society of Agronomy, Madison, Wisconsin.
- * American Society of Testing and Materials, 1992. Annual Book of ASTM Standards, Volume 4.08; Soil and Rock; Dimension Stone; Geosynthetics.

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- * Soil Survey Staff, 1972. Soil Survey Laboratory Methods.
- * Soil Survey Staff, Soil Conservation Service, National Soil Survey Handbook, title 430-VI (Washington D.C., U.S. Government Printing Office, November, 1993).
- * Virginia Department of Highways and Transportation, 1978. Virginia Test Manual.
- * NWWA/EPA Series RCRA Groundwater Monitoring Technical Enforcement Guidance Document, Sept. 1986.
- * Conrad, E. T., et al., 1981. Solid Waste Landfill Design and Operation Practices, Environmental Protection Agency, Washington, D. C.
- * The International Code Council, Building and Residential Codes.
- * Virginia State Sewage Disposal and Handling Regulations.
- * Loudoun County Codified Ordinance, Chapter 1040 (Water Wells) and Chapter 1066 (Private Sewage Disposal Systems).
- * Interpretive Guide to the Use of Soils Maps, Loudoun County, Virginia, 2000, County Extension Office, Loudoun County, Department of Building and Development.
- * Sowers, G.F. Introductory Soils Mechanics and Foundations: Geotechnical Engineering, Fourth Edition, Macmillan Publishing Co., Inc., N.Y.
- Terzaghi, K., Peck, R.B and Mesri, G. (1966), Soil Mechanics in Engineering Practice, 3rd, ed. Wiley-Interscience
- Braja, M. Das, Jonathan Wickert. (2005) Introductory Principles of Geotechnical Engineering, Sixth Edition, Thomas Learning College
- Budhu, Muni (2006). Soil Mechanics and Foundations, Second Edition, John Wiley & Sons, Inc.

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- Bowles, J. (1996) , Foundation Analysis and Design, Fifth Edition, McGraw-Hill Publishing Company
- Kramer, Steven L. (1996), Geotechnical Earthquake Engineering, Prentice-Hall, Inc.
- Rajapakse, Ruwan, (2008), Pile Design and Construction, Butterworth-Heinemann
- Loudoun County Karst Feature Database – The County maintains an informational database of the following features within the LOD, which shall be updated based on information in Geophysical Studies provided by applicants for land disturbing activities and land development applications within the LOD, information identified in Preliminary Soils Reviews as required by the Facilities Standards Manual, Revised United States Geologic Survey (USGS) Geological Mapping updates, and information provided through field inspections:
 - (a) The known extent of the Limestone Bedrock Formations (Sensitive Limestone Areas);
 - (b) Sinkholes, Swallets and Closed Depressions;
 - (c) Rock Outcrops;
 - (d) Springs;
 - (e) Cave Openings; and
 - (f) Perennial Sinking Streams.

6.200 HYDROGEOLOGIC TESTING

Hydrogeologic testing as set forth in this document is an evaluation of groundwater quantity and quality and the potential effects that a proposed land development may have on water resources. The evaluation is based on both on-site hydrogeologic testing and existing and readily available information. Hydrogeologic testing and reports are required and specifically defined for four

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general types of land development applications: (1) residential subdivisions not served by central water and sewer (further divided into those with wells on individual lots and those with communal systems); (2) solid waste facilities (for example landfills), (3) resource extraction areas (for example quarries and mines), and (4) other types such as certain industrial, irrigation, commercial, and recreational developments.

Described below are the requirements for hydrogeologic testing and reports as related to the general types of land development applications. Each hydrogeologic test shall be performed by or under the direct supervision of a professional geologist certified by the Commonwealth of Virginia. A report of the evaluation, the Hydrogeologic Report, shall be prepared and signed by the professional geologist and submitted to the County for review. Where not specifically defined in Chapter 6.200, the methodology used for testing and evaluation shall follow generally accepted professional hydrologic and hydrogeologic practices and standards. Examples of documents and sources considered representative of professional standards and methods are included in section 6.250.

6.210 HYDROGEOLOGIC TESTING REQUIREMENTS FOR SUBDIVISIONS NOT SERVED BY CENTRAL WATER AND SEWER

A hydrogeologic report for subdivisions will examine the local hydrogeologic conditions and the relationship between the proposed land use and those conditions. The testing will focus on the groundwater quantity and quality as they relate to the requirements of the proposed subdivision and the potential impacts the subdivision may have on the water resources. A hydrogeologic report is required prior to a preliminary subdivision submission in accordance with Section 8.102.B of this manual.

Subdivisions not served by central water and sewer can be divided into two groups based on the type of water supply system; those having a private well on each individual lot and those having communal (community) water systems serving multiple lots. Many of the requirements for hydrogeologic evaluation are the same for both types of water supply systems and will be listed in this section (6.210). However, there are a number of requirements that are specific to either communal systems or wells on individual lots and will be listed separately in sections 6.211 and 6.212, respectively.

A. Applicability of Hydrogeologic Testing for Subdivision Water Supply Approvals

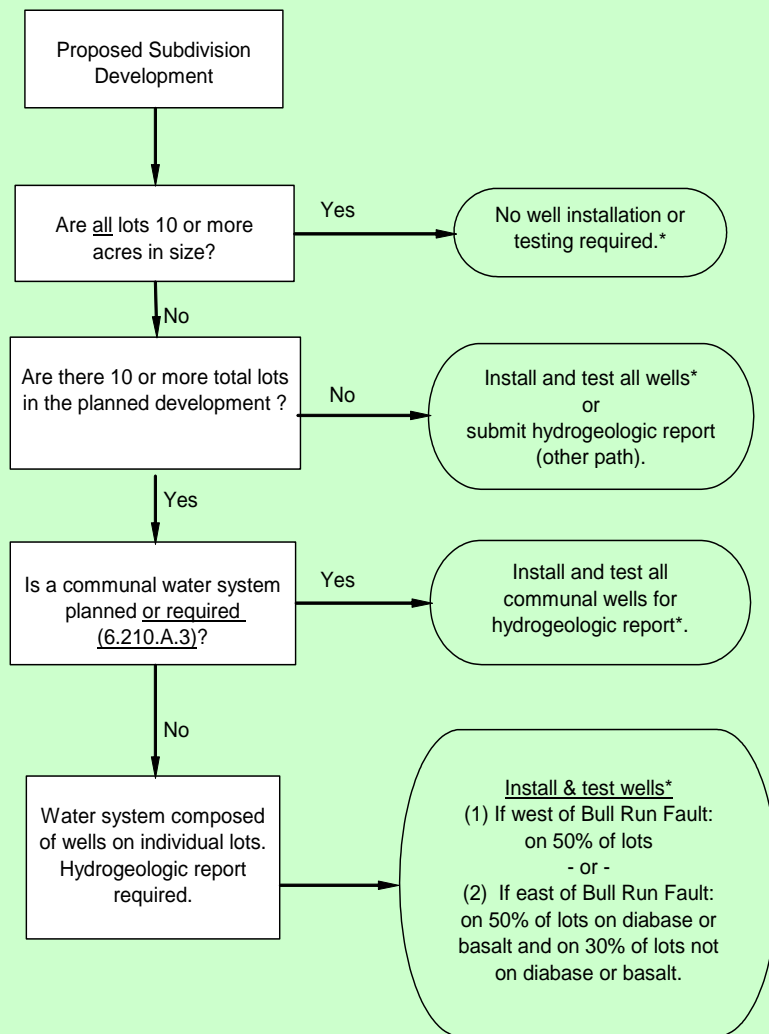
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1. The hydrogeologic testing requirements and procedures must be conducted on any new subdivision having any lots of less than ten (10) acres, except as provided in subparagraph 2 below.
2. If the number of proposed lots is nine (9) or less, the applicant has the option of either conducting Hydrogeologic Testing or drilling and successfully testing a well for water quantity and quality on each lot in accordance with the requirements of the Codified Ordinances of Loudoun County, Chapter 1040 (Water).
3. Hydrogeologic testing shall be required for all communal water supply systems.

Prior to obtaining permits or initiating any site preparation, hydrogeologic testing, or well installation within the MDOD or steep slopes, the applicant shall provide a conceptual site layout and obtain a Locational Clearance through the County in accordance with Sections 4-1600 or 5-1508 of the Zoning Ordinance.

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Figure 6.210-1: Flowchart for Identifying Type of Water System and Well Drilling and Testing Requirements for Subdivision Developments in Loudoun County.



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*Any development in Mountainside Development Overlay District (MDOD), *Limestone Overlay District (LOD)*, or steep slopes, as defined in Loudoun County Zoning Ordinance, must obtain a Locational Clearance from the County prior to any permits or land disturbing activity.

B. Background Information

Conduct a background evaluation of the hydrogeology using readily available existing resources such as publications and/or data from the U.S. Geological Survey, State of Virginia Water Control Board, U.S. Environmental Protection Agency, Loudoun County Department of Health, Department of Building and Development and the Office of Mapping and Geographic Information. At a minimum, extend the evaluation to include the area within approximately one (1) mile beyond the property boundary. Such evaluation shall include the following:

1. USGS and Loudoun County topographic information, whichever is more detailed.
2. Property plats and aerial photographs.
3. Geologic maps and data reports (well logs, water quality analysis, geologic information).
4. Existing well data or descriptive statistical summary of the same (e.g., minimum, maximum and mean of well depths and yields).
5. Reference existing research reports, hydrogeologic reports, geophysics reports, etc.
6. Existing pollution sources (e.g., underground storage tanks, septic fields, graveyards, etc) of record or those observed on site and within a minimum of 2,000 feet of the site boundary. An attempt shall be made to verify sources of record by field reconnaissance. The report shall contain a copy of a study from a company (or companies) that specializes in federal and state database searches for historical pollution source reporting. The report shall contain statements as to the type of background investigation conducted for pollution sources, the results of the investigation, and a verification statement that certifies that this historical pollution search has been conducted.

6.211 SUBDIVISIONS WITH COMMUNAL WATER SYSTEMS

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The testing and analyses specified in this section shall be conducted for subdivisions planning to use communal (formerly termed community) water systems. These shall include all communal systems, including those with fourteen (14) or fewer connections.

A. Analysis of Background Information

1. Using the background information compiled previously, conduct an evaluation of the site hydrogeology and the occurrence, quality, and quantity of groundwater, including:
 - a. Preliminary field verification of existing geologic information including rock outcrops, karst features, etc.
 - b. Analysis of fracture fabric: At sites with bedrock outcrops, fracture orientations (strike and dip measurements) shall be measured and documented in the report. The number and orientations of linear features or photo lineaments shall be analyzed and correlated with documented bedrock fractures.
 - c. Groundwater budget analysis: The effects of the proposed development on groundwater shall be evaluated using water budget concepts. The evaluation shall include available recharge under normal (10 inches/year) and drought (6 inches/year) conditions and net consumption of groundwater by the development at a rate specific and appropriate to the conditions and intended use. The evaluation should also include groundwater baseflow to streams using, when possible, available data from the subwatershed in which the proposed development is located.
2. Prioritization of groundwater zones: Based upon the data derived from the preliminary field verification, analysis of fracture fabric and groundwater budget analysis, each groundwater zone shall be delineated and prioritized according to the probability of developing the groundwater resources. Each of these zones shall be placed on a map (acceptable scales 1:2400 to 1:12000) identifying all probable or favorable zones and ranking the zones by their estimated relative potential to develop water for the proposed development.
3. A geophysical investigation shall be conducted on each zone being considered for drilling of a communal well. The geophysical method used and the area of

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investigation shall be appropriate for the hydrogeologic conditions and purpose of the study. A summary of the investigation shall be included in the report with a copy of all logs, field data, and data interpretations provided to the County if requested.

B. Water Supply Testing

Wells shall be installed and tested to provide evidence that the hydrogeologic system is capable of furnishing and sustaining the potable water needs of the eventual inhabitants of the proposed development. Well construction and testing shall be performed in accordance with the latest revisions of the Waterworks Regulations of the Virginia Department of Health, the Loudoun County Codified Ordinances, and Loudoun County Sanitation Authority water system standards, whichever is more stringent.

1. Wells: For each proposed water supply (planned production) well installed, a minimum of two (2) observation wells will be constructed unless suitable existing observation wells are available. However, in LOD, the minimum number of observation wells shall be the number necessary to identify a wellhead's zone of influence (i.e. The area surrounding a pumping well within which the water table or potentiometric surface has been changed due to the well's pumping) The locations of the observation wells shall be proposed by the applicant to the Loudoun County Department of Health and the Department of Building and Development for approval.
2. Formation Sampling: During all drilling, representative samples shall be collected for each change in geologic formation encountered and at intervals of twenty (20) feet when in the same geologic formation. The applicant shall retain these samples for a period of one (1) year after the study has been approved and be provided to the County if requested. A Virginia Certified Professional Geologist shall complete a geologic drilling log for each well constructed for the investigation.
3. Aquifer Pumping Test: An aquifer pumping test shall be conducted on each proposed communal water supply well that is constructed.
 - a. Method and Rate: Each test shall employ the down-hole method of pumping and be at a continuous and constant rate. A pumping rate shall be used that reasonably stresses the aquifer but does not result in excessive

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drawdown in the well. The minimum acceptable pumping rate for the test shall be one (1) gallon per minute (gpm) for each proposed equivalent hookup. The selected pumping rate shall not vary by more than 10 percent during the test. Discharge water shall be conveyed downgradient a sufficient distance (minimum 200 feet) from the pumping and observation wells, or to an impermeable conveyance feature (e.g., storm drain) or stream, to prevent recharge to the aquifer that could affect the test results.

- b. Duration: Pumping shall be continuous for not less than seventy-two (72) hours and shall continue until the water level in the well reaches equilibrium or near equilibrium conditions. Immediately upon completion of pumping, the recovery phase of the test shall begin and continue for a period equal to the duration of pumping or until the water level in the pumping well recovers to within 90 percent of the pre-pumping water level, whichever occurs first.
- c. Monitoring: The rate of discharge from the pumping well shall be measured and recorded at standard intervals during the test. (See Section 6.250 for references of standards and guidelines.) Water levels in the pumping and observation wells shall be monitored during the pumping phase and recovery phase of the test. All water level drawdown and recovery measurements shall be made at standard intervals. Monitoring shall include pre-test measurements of water levels in the pumping well and observation wells to identify possible water level trends. Pre-test monitoring shall be for a period of at least 48 hours immediately prior to the start of pumping.

C. Laboratory Testing for Water Quality.

- 1. For all proposed communal wells, tests shall be conducted to provide evidence that the system is capable of providing potable water. Such tests shall be conducted in accordance with the latest revision of the Waterworks Regulations of the Virginia Department of Health. Water quality testing results to satisfy this requirement shall be applicable for not more than three (3) years after sample collection unless the subdivision plat or plats for the entire subdivision have been recorded.

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2. The County may require additional water quality sampling if a well has one or more of the water quality test results listed below in subparagraphs a through c. The Applicant shall notify the County Department of Health and County Department of Building and Development prior to conducting any additional sampling.
 - a. The presence of any regulated contaminant at a concentration above the maximum contaminant level as defined in the latest version of the Waterworks Regulations of the Virginia Department of Health.
 - b. The presence of any unregulated contaminant as defined in the latest version of the Waterworks Regulations of the Virginia Department of Health at a concentration equal to or greater than the laboratory's detection or reporting limit.
 - c. The presence of any hazardous compound associated with either regulated or unregulated contaminants [e.g., methyl tertiary butyl ether (MTBE)] at a concentration equal to or greater than the laboratory's detection or reporting limit.

D. Well Protection

Upon completion of all testing, the applicant shall assure that each well is secured and permanently protected until being put in use by:

1. Installing a lockable well cap with lock or welding a piece of flat steel that completely seals the well casing; and
2. Placing a seven (7)-foot post of a bright, visible color next to the well casing to ensure visible identification of the well.

6.212 SUBDIVISIONS WITH INDIVIDUAL WELLS

The testing and analyses specified in this section shall be conducted for proposed subdivisions planning to use a private well on each individual lot. A summary of the well drilling and testing

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requirements for various proposed subdivision development scenarios is presented in Figure 6.210-1.

A. Analysis of Background Information

Using the background information compiled previously, conduct an evaluation of the site hydrogeology and the occurrence, quality, and quantity of groundwater, including:

1. Preliminary field verification of existing geologic information including rock outcrops, karst features, etc.; and
2. Groundwater budget analysis: The effects of the proposed development on groundwater shall be evaluated using water budget concepts. The evaluation shall include available recharge under normal (10 inches/year) and drought (6 inches/year) conditions, net consumption of groundwater by the development at a rate specific and appropriate to the conditions and intended use, and groundwater baseflow to streams using, when possible, available data from the subwatershed in which the proposed development is located.
3. Analysis of fracture fabric: At sites with bedrock outcrops, fracture orientations (strike and dip measurements) shall be measured and documented in the report. The number and orientations of linear features or photolineaments shall be analyzed and correlated with documented bedrock fractures.

B. Water Supply Testing

A portion of the proposed total number of wells shall be installed and tested to provide evidence that the hydrogeologic system is capable of furnishing and sustaining the potable water needs of the proposed development. Well construction and testing shall be performed in accordance with the latest revisions of the Waterworks Regulations of the Virginia Department of Health and the Loudoun County Codified Ordinances, whichever is more stringent.

1. Wells: All wells shall be designed to meet standards defined in Chapter 1040 of the Loudoun County Codified Ordinance. The proposed locations of the wells shall be submitted by the applicant as part of a subdivision layout showing proposed well sites for each building lot to the Loudoun County Department of Health and the Department of Building and Development for approval. The

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number and general placement of test wells shall be based on the following criteria:

- a. A minimum of three (3) test wells shall be required for each study.
 - b. Selected test well sites shall include at least one well on each unique combination of landform and geologic formation on which wells are proposed.
 - c. Lots located west of the Bull Run Fault: Test wells shall be installed and tested on fifty percent (50%) of the proposed lots.
 - d. Lots located east of the Bull Run Fault: Test wells shall be installed and tested on fifty percent (50%) of the proposed lots with any portion of the lot overlying diabase or basalt rock and on thirty percent (30%) of the lots having no portion of the lot overlying diabase or basalt rock.
 - e. Where individual wells are proposed for each lot, physical or chemical alteration of geologic materials or structures (e.g., hydraulic fracturing, use of explosives, or addition of chemicals) to increase yield of test wells will not be permitted prior to the pumping test.
2. Formation Sampling: During all drilling, representative samples shall be collected for each change in geologic formation encountered and at intervals of twenty (20) feet when in the same geologic formation. The applicant shall retain these samples for a period of one (1) year after the study has been approved and be provided to the County if requested. A Virginia Certified Professional Geologist shall complete a geologic drilling log for each well constructed for the investigation.
 3. Aquifer Pumping Test: An aquifer pumping test shall be conducted on each well constructed for water supply testing. For each pumping well test, the two closest available test wells shall be monitored as observation wells unless otherwise approved by the County.
 - a. Method and Rate: Each test shall employ the down-hole method of pumping and be at a continuous and constant rate. A pumping rate shall

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be used that reasonably stresses the aquifer but does not result in excessive drawdown in the well. The minimum acceptable pumping rate for the test shall be one (1) gpm. Generally, the maximum required pumping rate shall be 20 gpm unless otherwise directed by the County. The selected pumping rate shall not vary by more than 10 percent during the test. Discharge water shall be conveyed downgradient a sufficient distance (minimum 200 feet) from the pumping and observation wells, or to an impermeable conveyance feature (e.g., storm drain) or stream, to prevent recharge to the aquifer that could affect the test results.

- b. Duration: Pumping shall be continuous for not less than eight (8) hours and, if possible, continue until the water level in the well reaches equilibrium or near-equilibrium conditions. Immediately upon completion of pumping, the recovery phase of the test shall begin and continue for a period equal to the duration of pumping or until the water level in the pumping well recovers to within 90 percent of the pre-pumping water level, whichever occurs first.
- c. Monitoring: The rate of discharge from the pumping well shall be measured and recorded at standard intervals during the test. (See Section 6.250 for references of standards and guidelines.) Water levels in the pumping and observation wells shall be monitored during the pumping phase of the test and the pumping well shall be monitored during the recovery phase of the test. All water level drawdown and recovery measurements shall be made at standard intervals. Monitoring shall include pre-test measurements of water levels in the pumping well and observation wells to identify possible water level trends and shall be for a period of at least 8 hours immediately prior to the start of pumping.

C. Laboratory Testing for Water Quality

- 1. Water quality sampling and analyses shall be conducted on each test well to provide evidence that the local groundwater system is capable of providing potable water. Such tests shall be conducted in accordance with the latest revision of the Chapter 1040 of the Codified Ordinances of Loudoun County. Water quality testing results to satisfy this requirement shall be applicable for not more

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than three (3) years after sample collection unless the subdivision plat or plats for the entire subdivision have been recorded.

2. The County may require additional water quality sampling if a well has one or more of the water quality test results listed below in subparagraphs a through c. The Applicant shall notify the County Department of Health and County Department of Building and Development prior to conducting any additional sampling.
 - a. The presence of any regulated contaminant at a concentration above the maximum contaminant level as defined in the latest version of the Waterworks Regulations of the Virginia Department of Health.
 - b. The presence of any unregulated contaminant as defined in the latest version of the Waterworks Regulations of the Virginia Department of Health at a concentration equal to or greater than the laboratory's detection or reporting limit.
 - c. The presence of any hazardous compound associated with either regulated or unregulated contaminants (e.g., methyl tertiary butyl ether [MTBE]) at a concentration equal to or greater than the laboratory's detection or reporting limit.

D. Well Protection

Upon completion of all testing, the applicant shall assure that each well is secured and permanently protected until being put in use by:

1. Installing a lockable well cap with lock or welding a piece of flat steel that completely seals the well casing; and
2. Placing a seven (7)-foot post of a bright, visible color next to the well casing to ensure visible identification of the well.

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6.213 REPORTING REQUIREMENTS

The detailed hydrogeologic report shall include, at a minimum, the items described in paragraphs A through ~~M~~ ~~P~~ N below. All report material shall be organized by either “type” (well completion reports, pumping test analyses, water quality reports, etc.) or by well, in tabbed appendices clearly marked showing the content of the tabbed section. Identification of test sites, field data, laboratory reports, and test analyses must all match exactly. Raw field data (and corrected data if used) from the pumping tests and a tabulated summary of well drilling and testing results (including items listed below in sections F, G, and, unless pre-approved by the County, section H) shall be included with the report in a digital format acceptable to the County.

A. General Discussion

A discussion of the geologic setting, local watershed, hydrogeologic units, land surface elevation and relief, occurrence and movement of surface water and groundwater, and interpretation of groundwater data from surrounding areas, including groundwater quality.

B. Maps

A map or set of maps (scales from 1:2400 [1 inch = 200 feet] to 1:12000 [1 inch = 1,000] feet and with north arrows and explanations as needed) covering the development proposal. The map(s) shall contain all existing planimetric features, topography with 5-foot contour intervals, NAD 1983 HARN ~~1927~~ Virginia North State plane grid system, all proposed roads, proposed lot lines, proposed lot sites, proposed house sites, proposed septic fields, surface water features, and springs. Groundwater contours with data control points and direction of groundwater flow shall be illustrated.

C. Cross-Sections

The report shall contain one or more cross-sections, at true horizontal scale and vertical scale (exaggerated as appropriate). The location of each cross-section shall be shown on the plan view map and the cross-section shall contain the following information:

1. Geologic data including regolith, bedrock, and structural features if present.
2. Well site locations showing well casings, total depths, and specific capacities.

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3. Elevations of ground surface, rock formations, and static water surfaces.
4. Final water level in each pumped well at the end of the pumping tests and the corresponding pumping rate of the well.

D. Geologic Logs

For each well drilled for the investigation, a geologic log shall be completed and sealed by a Virginia Certified Professional Geologist. A Virginia Water Well Completion Report (form GW-2) shall be completed for each well and signed by the driller who shall be licensed to do business in Loudoun County. The geologic log shall contain the NAD 1927 Virginia North State Plane coordinates and land surface elevation of the well.

E. Well Construction Diagrams

For each well constructed for the investigation, provide a well construction diagram with vertical scale showing (when applicable) the well number, well permit number, date of construction, well location coordinates, land surface elevation, total depth, well casing depth, grout depth, bentonite seal thickness, top and bottom of well screen, height of casing above land surface, static water level and date, depth of distinct water bearing zones and estimated contribution per zone, and corresponding graphic (symbol) geologic log with generalized descriptive text.

F. Well Construction Summary

For all wells constructed for the investigation, provide a summary table which includes, at a minimum, the well I.D. number, well construction permit number, completion date, land surface elevation, total well depth, well casing depth, depth to bedrock, static water level (all on the same date), total well yield and yield test method, and depths and estimated yields of water producing zones.

G. Well Testing Summary

In either the well construction summary table (previous item) or a separate table, summarize the well testing results, including at a minimum, the well number (and pumping well number if different), date tested, duration of pumping, pumping rate, pre-pumping (static) water level, maximum observed water level drawdown, distance to pumped well, percent of available drawdown used (assume maximum available

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drawdown is 40 feet above well bottom or use more stringent criteria if appropriate), specific capacity, transmissivity, storativity (if available), and time to achieve 90 percent recovery (or the percent recovery after a specified time) in the pumped well.

H. Groundwater Quality

For all wells tested for the investigation, provide a table summarizing the groundwater quality and include, at a minimum, the concentrations of any compounds exceeding the maximum contaminant levels as defined in the latest version of the Waterworks Regulations of the Virginia Department of Health and any detected organic compound or pesticide. Copies of the laboratory reports shall be included in the appendices.

I. Water Balance

The report shall develop groundwater mass balance and recharge estimates for the area. Applicable calculations and references shall be included as well as assumptions and limitations of the methods used. The report shall include a discussion of the following information, including appropriate supporting calculations and diagrams, which shall include, at a minimum:

1. Identification of the source or sources of recharge, using recharge from rainfall for normal conditions of 10 inches per year and for drought conditions of 6 inches per year.
2. The calculated effect of all proposed subdivision wells pumping at a daily net consumption rate specific and appropriate to the conditions and intended use. For subdivisions with communal water systems, provide calculations for both of the following conditions:
 - a. At a rate that does not include lawn and landscape irrigation.
 - b. At a rate that does include irrigation of private lawns and any irrigated common area lawns and landscaping. Irrigation rates used in calculations shall follow normal recommendations for the area (e.g., 1 inch of water per week for turf lawns during dry periods).

J. For communal systems in LOD, prepare:

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1. A wellhead protection plan to include:
 - a. Delineation of wellhead's zone of influence. The methodology used to delineate the zone of influence shall be technically based on site-specific data, and be appropriate to Hydrogeologic conditions and the withdrawal rate of the intended use. The methodology chosen shall be referenced and justified in terms of its appropriateness.
 - b. Estimation of sustainable yield (i.e. the average rate of pumping that can be maintained without endangering either the quantity or quality of groundwater.)
 - c. Pumping schedule.
 - d. Number and location of independent backup wells.
 2. An analysis and evaluation of the impact of groundwater withdrawals on the groundwater and surface water resources including the impact on surrounding water supply wells
 3. A plan for investigating potential impacts on existing off-site water supply wells within a minimum of 1,000 feet of the proposed development's production wells if the off-site wells experience water level or water quality problems during periods of production well use. Initial mitigation measures would include demand management strategies.
- K. Nitrate Loading Computations shall be performed in accordance with the Loudoun County Department of Health memorandum dated February 27, 1989.
- L. Evaluate the possibility of wells on the remaining (non-tested) individual lots having inadequate yield and propose how these may be addressed.
- M. Aquifer Test Analyses

The transmissivity and storativity of the various materials evaluated by aquifer tests interpreted using professionally accepted methods. Indicate the analytical method used, the appropriateness of the selected method relative to the hydrogeologic conditions, and

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show a summary of calculations. If there are significant background trend effects that are identified in the pre-test monitoring data or by other means, then the pumping test data shall be corrected for these effects prior to analysis and the corrected data shown on a graph.

N. Safe Yield Evaluation

Testing results and topics pertinent to the concept of “safe yield” shall be presented and discussed under a separate heading of the report. The methods used in the evaluation along with the method's assumptions and limitations shall be explained. For the purposes of this report, the safe yield evaluation shall encompass the assessment of the effects from the combined groundwater withdrawal of the proposed subdivision. These effects shall include but not be limited to:

1. Estimated extent of the one (1)-foot drawdown contour using representative values of transmissivity and storativity (based on the on-site testing) and a net withdrawal rate of 150 gpd per household or the rate used in paragraph 6.213.I.2 above, whichever is greater.
2. Alteration of groundwater flow direction including a map showing estimated groundwater contours and flow directions resulting from the effects of the net withdrawal rate used in the calculations for paragraph 6.213.I.2 above or based on more accurate data if available. This map shall be on the same base and scale as the pre-development groundwater contour and flow map required in paragraph 6.213.B.
3. The potential adverse or undesired affects to the water resources caused by the estimated combined groundwater withdrawal from all of the proposed development wells (items 1 and 2 above). Examples of adverse affects are the possibilities of lowering or depleting on-site surface water or groundwater sources and drawing in or altering the flow direction of groundwater from potential pollution sources such as leaking USTs, ASTs, waste water, or other zones of contaminated surface or groundwater. Such discussion should also address the potential for lowering or depleting offsite surface water or groundwater sources.

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6.220 HYDROGEOLOGIC REPORT REQUIREMENTS FOR SOLID WASTE FACILITIES

Refer to the most recent versions of Chapter 1080 of the Codified Ordinances of Loudoun County and the Virginia Solid Waste Management Regulations for the hydrogeologic report requirements for solid waste facilities.

6.230 HYDROGEOLOGIC REPORT REQUIREMENTS FOR RESOURCE EXTRACTION

The following information, testing, analyses, and reporting are required at a minimum:

A. Background Information

Conduct a background evaluation of the hydrogeology using readily available existing resources such as publications and/or data from the U.S. Geological Survey, State of Virginia Water Control Board, U.S. Environmental Protection Agency, Loudoun County Department of Health, and Office of Mapping and Geographic Information. At a minimum, extend the evaluation to include the area within approximately one (1) mile beyond the property boundary.

1. USGS and Loudoun County topographic information, whichever is more detailed.
2. Property plats and aerial photographs.
3. Geologic maps and data reports (well logs, water quality analysis, geologic information).
4. Existing well data or descriptive statistical summary of the same. (For example, minimum, maximum and mean of well depths, water levels, etc.).
5. Reference existing research reports, hydrogeologic reports, geophysics reports, etc.
6. Existing pollution sources (e.g. underground storage tanks, septic fields, graveyards, etc) of record or observed on site and within a minimum of 2,000 feet of the site boundary. An attempt shall be made to verify sources of record by field reconnaissance. The report shall contain a copy of a study from a company or companies that specialize in federal and state database searches for historical

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pollution source reporting. The report shall contain statements as to the type of background investigation conducted for pollution sources, the results of the investigation, and a verification statement that certifies that this historical pollution search has been conducted.

B. Analysis of Background Information

Using the background information compiled previously, conduct an evaluation of the site hydrogeology including:

1. Preliminary field verification of existing geologic information including rock outcrops, karst features, etc.
2. Analysis of fracture fabric: At sites with bedrock outcrops, fracture orientations (strike and dip measurements) shall be measured and documented in the report. The number and orientations of linear features or photo lineaments shall be analyzed and correlated with documented bedrock fractures.
3. Locations and identifications of all wells within 2,000 feet of the proposed area of resource extraction or production wells.
4. Water budget analysis: The effects of the proposed development on groundwater and surface water discharges shall be evaluated using water budget concepts. The evaluation shall include available recharge under normal and drought conditions, net consumption of groundwater by the development, and groundwater baseflow to streams using, when possible, available data from the subwatershed in which the proposed development is located.

C. Geophysical Survey

A geophysical survey shall be conducted to investigate zones adjacent to the proposed resource extraction area that may be sensitive to soil/rock removal or dewatering activities in the form of reduced stability or increased groundwater flow. Information from the background data analyses shall be used to assist in targeting potential transects for the surveys. The geophysical method or methods used shall be appropriate for the hydrogeologic conditions and purpose of the study. A summary of the survey shall be presented in the report including a description of the methods used, diagrams of the survey transect locations, an interpretation of the data, and an analysis of the findings

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with respect to the proposed land use. A copy of all logs, field data, and data interpretations shall be provided to the County if requested. Results of the survey shall be used to help select sites for additional investigation, well construction, and aquifer testing.

D. Geology

For each well drilled for the investigation, lithologic samples shall be collected at intervals of 10 feet or change in lithology, whichever is less. Geologic logs shall be completed and sealed by a Virginia Certified Professional Geologist. The Applicant shall retain these samples for a period of one (1) year after the study has been approved and provide them to the County if requested.

E. Pumping Test

The minimum number of pumping tests required is contingent on acreage, layout, and volume of the proposed area of resource extraction. The tests shall include:

1. Wells: For each well to be tested, a minimum of two (2) observation wells will be required. Additional existing wells shall be monitored as observation wells if they are available and within a distance that is reasonable to expect measurable impacts from the pumping test. The locations of the wells intended for monitoring shall be proposed by the applicant and approved by the Loudoun County Department of Health and the Department of Building and Development. If dewatering will be part of the proposed resource extraction process, a series of test wells near the edge of the proposed extraction area shall be installed and completed to a depth below the planned level of dewatering for use in simulating dewatered conditions.
2. Method and Rate: Each test shall employ the down-hole method of pumping and be at a continuous and constant rate. A pumping rate shall be used that reasonably stresses the aquifer but does not result in excessive drawdown in the well. The selected pumping rate shall not vary by more than ten (10) percent during the test. If test wells are pumped to simulate dewatered conditions, the pumping test shall be a constant drawdown test and the water level in the well shall be quickly pumped down to and held at or below the planned level of dewatering. In all cases, discharge water shall be conveyed downgradient a sufficient distance (minimum 200 feet) from the pumping and observation wells,

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or to an impermeable conveyance feature (e.g., storm drain) or stream, to prevent recharge to the aquifer that could affect the test results.

3. Duration: Pumping shall be continuous for not less than forty-eight (48) hours and continue until the water level reaches equilibrium or near-equilibrium conditions. Immediately upon completion of pumping, the recovery phase of the test shall begin and continue for a period equal to the duration of pumping or until the water level in each well (and at each surface water site) recovers to within 90 percent of the pre-pumping water level, whichever occurs first.
 4. Monitoring: The rate of discharge from each pumping well shall be measured and recorded at standard intervals during the test. (See Section 6.250 for references of standards and guidelines.) Water levels in the pumping and observation wells shall be monitored during the pumping phase and recovery phase of the test. All water level drawdown and recovery measurements shall be made at standard intervals. Monitoring shall include pre-test measurements of water levels in the pumping well and observation wells to identify possible water level trends. Pre-test monitoring shall be conducted for a period of at least 48 hours immediately prior to the start of pumping. If there are significant background trend effects that are identified in the pre-test monitoring data or by other means, then the pumping test data shall be corrected for these effects prior to analysis and the corrected data shown on a graph. The water level of ponds, streams, and springs within the immediate vicinity of the pumping well(s) shall be measured on an hourly basis for the duration of pumping. Where appropriate and technically feasible, flow measurements shall be recorded in streams and springs at a minimum of every six (6) hours. Pre-test monitoring of surface waters shall be conducted for a period of at least 48 hours immediately prior to the start of pumping.
- F. The transmissivity and storativity of the aquifer(s) based on aquifer tests evaluated using professionally accepted methods. Indicate the analytical method used, the appropriateness of the selected method relative to the hydrogeologic conditions, and show a summary of the calculations including data plots and curve matching.
- G. Groundwater monitoring program proposal to include:
1. Monitoring well locations and construction specifications.
 2. Monitoring and reporting frequency.

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3. Water quality sampling and analysis plan (methodologies according to Virginia Groundwater Quality or ASTM Standards, whichever is more stringent).
 4. Well maintenance and security.
- H. Hydrogeologic cross-sections showing the geology, proposed area of extraction (include diagrams showing before extraction and after extraction conditions), well casings and total depths, and static groundwater levels.
- I. Include an evaluation on the impact of the proposed extraction operations (including but not limited to dewatering) on surrounding geologic stability, groundwater and surface water
- J. For existing and future off-site water supply wells within a minimum of 1,000 feet of the proposed resource extraction area, quantity and quality baseline testing prior to extraction shall be conducted and submitted and a ~~A~~ plan for investigating and mitigating the potential impacts on existing off-site water supply wells within a minimum of 1,000 feet of the proposed resource extraction area if the off-site wells experience water level or water quality problems while the extraction process or dewatering is active.
- K. Include all water level monitoring and pumping data used in the report in a digital format acceptable to the County.

6.240 HYDROGEOLOGIC REPORT REQUIREMENTS FOR OTHER DEVELOPMENTS

Other types of developments that withdraw groundwater, including but not limited to recreational developments (golf courses, water theme parks, etc.), large non-agricultural irrigation systems, and industrial or commercial developments with water demands potentially exceeding an average of ten thousand (10,000) gallons per day during any single thirty (30)-day period. Also included are proposed agricultural developments potentially withdrawing more than one million (1,000,000) gallons during any 30-day period. The minimum information, testing, analyses, and reporting requirements for other developments are listed in the section below. Given the wide range of these developments, the resulting potential impacts to groundwater and surface water resources may vary significantly. For some proposed developments, more rigorous testing and evaluation may be appropriate because of their planned groundwater needs or their location. It is recommended that the applicant, prior to conducting

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their investigation, arrange a meeting with the County to discuss their proposed development and find out if more rigorous testing and evaluation requirements are appropriate.

A. Background Information

Conduct a background evaluation of the hydrogeology using readily available existing resources such as publications and/or data from the U.S. Geological Survey, State of Virginia Water Control Board, U.S. Environmental Protection Agency, Loudoun County Department of Health, and Office of Mapping and Geographic Information. At a minimum, extend the evaluation to include the area within approximately one (1) mile beyond the property boundary.

1. USGS and Loudoun County topographic information, whichever is more detailed.
2. Property plats and aerial photographs.
3. Geologic maps and data reports (well logs, water quality analysis, geologic information).
4. Existing well data or descriptive statistical summary of the same. (For example, minimum, maximum and mean of well depths, water levels, etc.)
5. Reference existing research reports, hydrogeologic reports, geophysics reports, etc.
6. Existing pollution sources (e.g. underground storage tanks, septic fields, graveyards, etc) of record or observed on site and within a minimum of 2,000 feet of the site boundary. An attempt shall be made to verify sources of record by field reconnaissance. The report shall contain a copy of a study from a company or companies that specialize in federal and state database searches for historical pollution source reporting. The report shall contain statements as to the type of background investigation conducted for pollution sources, the results of the investigation, and a verification statement that certifies that this historical pollution search has been conducted.

B. Analysis of Background Information

Using the background information compiled previously, conduct an evaluation of the site hydrogeology including:

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1. Preliminary field verification of existing geologic information including rock outcrops, karst features, etc.
2. Analysis of fracture fabric: At sites with bedrock outcrops, fracture orientations (strike and dip measurements) shall be measured and documented in the report. The number and orientations of linear features or photo lineaments shall be analyzed and correlated with documented bedrock fractures.
3. Locations and identifications of all wells within 2,000 feet of the proposed development's production wells.
4. Water budget analysis: The effects of the proposed development on groundwater and surface water discharges shall be evaluated using water budget concepts. The evaluation shall include available recharge under normal and drought conditions, net consumption of groundwater by the development, and groundwater baseflow to streams using, when possible, available data from the subwatershed in which the proposed development is located.

C. Geophysical Survey:

Depending on the type of development and its water demands, the County may require that a geophysical survey be conducted to investigate subsurface conditions that can not be readily determined through other methods. The Applicant shall present the preliminary findings of the initial investigation (sections 6.240 A and B above) to the Loudoun County Department of Health and Department of Building and Development for a determination of the need for a geophysical study. If a geophysical survey is conducted, information from the background data analyses shall be used to assist in targeting potential transects for the surveys. The geophysical method or methods used shall be appropriate for the hydrogeologic conditions and purpose of the study. A summary of the survey shall be presented in the report including a description of the methods used, diagrams of the survey transect locations, an interpretation of the data, and an analysis of the findings with respect to the proposed land use. A copy of all logs, field data, and data interpretations shall be provided to the County if requested. Results of the survey shall be used to help select sites for additional investigation, well construction, and aquifer testing.

D. Geology

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For each well drilled for the investigation, lithologic samples shall be collected at intervals of 10 feet or change in lithology, whichever is less. Geologic logs shall be completed and sealed by a Virginia Certified Professional Geologist. The Applicant shall retain these samples for a period of one (1) year after the study has been approved and provide them to the County if requested.

E. Pumping Test

The minimum number of pumping tests required are contingent on acreage and layout of the proposed development and the volume and proposed use of groundwater.

1. Wells: For each well to be tested, a minimum of two (2) observation wells will be required unless otherwise approved by the County. Other test wells may be temporarily used as the required two observation wells provided they are within a distance that is reasonable to expect measurable impact from the test pumping well. (In addition to the two required observation wells, additional existing wells, if they are available, shall also be monitored as observation wells if they are relatively close to the pumping test well.) The locations of the wells intended for monitoring shall be proposed by the applicant and approved by the Loudoun County Department of Health and the Department of Building and Development.
2. Method and Rate: Each test shall employ the down-hole method of pumping and be at a continuous and constant rate. A pumping rate shall be used that reasonably stresses the aquifer but does not result in excessive drawdown in the well. The pumping rate shall not be less than the maximum anticipated daily withdrawal rate used in the proposed groundwater withdrawal plan (see Section 6.240.I). The selected pumping rate shall not vary by more than ten (10) percent during the test. Discharge water shall be conveyed downgradient a sufficient distance (minimum 200 feet) from the pumping and observation wells, or to an impermeable conveyance feature (e.g., storm drain) or stream, to prevent recharge to the aquifer that could affect the test results.
3. Duration: Pumping shall be continuous for not less than forty-eight (48) hours and continue until the water level in the well reaches equilibrium or near-equilibrium conditions. A minimum test duration greater than forty-eight (48) hours may be appropriate and required depending on the location and groundwater needs of the proposed development or to satisfy requirements of

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other agencies. Immediately upon completion of pumping, the recovery phase of the test shall begin and continue for a period equal to the duration of pumping or until the water level in each well (and each surface water site) recovers to within 90 percent of the pre-pumping water level, whichever occurs first.

4. **Monitoring:** The rate of discharge from each pumping well shall be measured and recorded at standard intervals during the test. (See Section 6.250 for references of standards and guidelines.) Water levels in the pumping and observation wells shall be monitored during the pumping phase and recovery phase of the test. All water level drawdown and recovery measurements shall be made at standard intervals. Monitoring shall include pre-test measurements of water levels in the pumping well and observation wells to identify possible water level trends. Pre-test monitoring shall be conducted for a period of at least 48 hours immediately prior to the start of pumping. If there are significant background trend effects that are identified in the pre-test monitoring data or by other means, then the pumping test data shall be corrected for these effects prior to analysis and the corrected data shown on a graph. The water level of ponds, streams, and springs within the immediate vicinity of the pumping well(s) shall be measured on an hourly basis for the duration of pumping unless otherwise approved by the County. Where appropriate and technically feasible, measurements shall be recorded in streams and springs at a minimum of every six (6) hours. Pre-test monitoring of surface waters shall be conducted for a period of at least 48 hours immediately prior to the start of pumping.
- F. Determination of aquifer transmissivity and storativity.
- G. Groundwater monitoring program proposal to include:
1. Monitoring well locations and construction specifications.
 2. Monitoring and reporting frequency.
 3. Water quality sampling and analysis plan (methodologies according to Virginia Groundwater Quality or ASTM Standards, whichever is more stringent).
 4. Well maintenance and security.

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- H. Hydrogeologic cross-sections showing the geology, proposed production wells, test and observation well casings, total depths, and static groundwater levels.
- I. Proposed groundwater withdrawal plan including estimated average and maximum withdrawals, by well, by month, for a one year period and the estimated maximum withdrawal for a one (1)-day period. Include a percentage breakdown of the major uses of the groundwater.
- J. An analysis and evaluation of the impact of groundwater withdrawals on the groundwater and surface water resources including the impact on surrounding water supply wells.
- K. A plan for investigating and mitigating potential impacts on existing off-site water supply wells within a minimum of 1,000 feet of the proposed development's production wells if the off-site wells experience water level or water quality problems during periods of production well use.
- L. Water Quality Sampling: Any well used or potentially used for potable water supply shall be sampled in accordance with the latest version of the Waterworks Regulations of the Virginia Department of Health. Contact the Loudoun County Department of Health for specific testing requirements.
- M. Include all water level monitoring and pumping data used in the report in a digital format acceptable to the County.

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6.250 REFERENCES OF STANDARD PRACTICES AND GUIDELINES

American Society for Testing and Materials (ASTM) Standards: D 653, Terminology Related to Soil, Rock, and Contained Fluids; D 2488, Practice for Description and Identification of Soils (Visual Manual Procedure); D 4043, Guide for Selection of Aquifer-Test Field and Analytical Procedures in Determination of Aquifer Properties by Well Techniques; D 4050, Standard Test Method (Field Procedure) for Withdrawal and Injection Well Tests for Determining Hydraulic Properties of Aquifer Systems; D 4105, Test Method (Analytical Procedure) for Determining Transmissivity and Storativity of Nonleaky Confined Aquifer by the Modified Theis Nonequilibrium Method; D 4106, Test Method (Analytical Procedure) for Determining Transmissivity and Storativity of Nonleaky Confined Aquifers by the Theis Nonequilibrium Method; D 4448, Standard Guide for Sampling Ground Water Monitoring Wells; D 4750, test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well); and D 5092, Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers. E 1527, Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process.

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